MORTALITY IN ENCHYTRAEID AND LUMBRICID POPULATIONS CAUSED BY HARD FROSTS

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Mortality in Enchytraeid and Lumbricid populations caused by hard frosts

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Animals living or overwintering in soil and litter are usually effectively protected against low temperatures by the snow cover. Some insects and spiders are even normally active under snow. Certain species of winter-active spiders have been reported to show a temperature preference of -3 - +3°C, but, nevertheless, a temperature of -5°C may be lethal to them.

If hard frosts occur when the snow cover is thin or missing, temperatures in the topsoil are expected to reach the lower tolerance limits of at least some species of soil invertebrates. Such a situation was observed in Finland in Novermber 1965. Temperatures of -7 - -8° were recorded in the humus of coniferous forests. At four of the 5 sampling sites, the density of Enchytraeids had dropped to 10 % or less of that before the frost period. The earthworn populations had suffered similarly.

At the end of December 1975 there was a warm period which melted the snow cover. This was followed by hard frosts, the daily mean near Helsinki reaching -15°C, and the minimum at soil surface -20°. In the middle of January it was still colder, (mean -20°, minimum -29°), the thickness of snow being now 10 cm. In 20 May 1976 the Lumbricid populations in a spruce forest near Helsinki consisted almost exclusively of very small, newly hatched worms, although in the previous autumn all age classes were present. The winter had destroyed most of the population, but the eggs had survived. The population biomass recovered by May 1977, and by the next autumn the new generation had reached maturity.

A similar destruction was observed in Enchytraeid populations of bogs 100 km north from Helsinki.

The Lumbricid species in question were Dendrobaena octaedra and Lumbricus rubellus. The Enchytraeid communities consisted mainly of Cognettia sphagnetorum.

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Animals must be adapted to withstand low temperatures normally occurring in their winter habitats. The temperature to which an overwintering animal is exposed depends on its position in the habitat. Animals living or overwintering in soil and litter are usually effectively protected against low temperatures by the snow cover. Thus e.g. HUHTA et al. (1967), during a four-year study including regular sampling in winter, only exceptionally recorded temperatures lower than -2 to -3°C in the humus layer of coniferous forests in Finland. Some insects and spiders are even normally active under snow. Certain species of Linyphiid spiders mate in winter, and before mating they must be exposed to low temperatures. The temperature preferendum of these species lies in winter between -1 and +3,5°C, but, nevertheless, a temperature of -5° may be lethal to them (WOLSKA 1957, BUCHE 1966, SCHAEFER 1976).

Exceptionally, hard frosts may occur when the snow layer is thin or absent. In such circumstances, the temperature in the topsoil is expected to sink to a level which could cause losses in populations of soil invertebrates. However, such losses have seldom been reported. BROLARSEN (1949) showed that populations of earthworms (Lumbricus rubellus, Dendrobaena octaedra) and dipterous larvae (Bibio lavigerus, Tipula paludosa) were very sparse after cold winters, whereas egg cocoons of Lumbricids survived. The author had not recorded soil temperatures, and considered that the losses were partly due to low precipitation in spring and early summer.

In the middle of November 1965 considerable frosts occurred in Finland before the snow cover (Fig. 1): the daily mean ranged between -8 and -10°C, and the minimum on soil surface was ca. -15°. One week later it was still colder (mean -14 to -16°, minimum -19 to -21°), the thickness of snow being only 7 cm. On 15 and 22 November the temperature of humus ranged between -3 and -8°, which was lower than on any previous sampling date during four years (Table 1 and 2). Between the two last samplings, one on 1 or 8 Nov., the other on 15 or 22 Nov. numbers of Enchytraeids and Lumbricids dropped abruptly. At 4 of the 5 sampling sites, the density of Enchytraeids was only 10 % or less, as compared with that prior to the frost period. (The data of HUHTA et al. 1967; sample size 15 units, 45 cm^2 each.) The fall in the numbers of earthworms was as marked, though only at one site the original

population was dense enough to show the decrease (sample size 4 x 625 cm^2).

The samples included only the organic soil (ca. 5 cm). In spite of this, the observed decrease in numbers can not be explained by migration into deeper soil layers, because even in frozen soil, most of the animals are normally present in the humus horizon (NURMINEN 1967).

In winter 1975-76 the weather conditions were exceptional. December 1975 was rather normal, thickness of the snow being up to 20 cm. But during a thaw period at the end of the month all the snow melted. Soon after that was a frost period with mean daily temperatures down to -15^{o}, and the minimum at soil surface down to -20^{o} (Fig. 2). On 5 Jan. 1976 a temperature recorder showed $\leqq -5^{o}C$ at depths of 5 and 12 cm in arable soil near Helsinki (this was the minimum of the recorder), and -2 to -3^{o} at 20 cm. Somewhat later there were still harder frosts: daily mean down to -20^{o}, minimum down to -29^{o}; the snow cover was now 10 cm in thickness.

During that winter, the populations of Enchytraeids (Cognettia sphagnetorum) in bog soils at Lammi (100 km north from Helsinki) suffered severely. On 5 May 1976 the mean density ranged from 0 to 5 per cent of that on 10 Nov. 1975 (J. Markkula, unpublished material; see Table 3). During the summer 1976 the populations gradually recovered.

During 1975-77, quantitative samples of Lumbricids were taken every autumn and spring from a spruce forest near Helsinki (Site 1 of HUHTA et al. 1967). The size of a total sample was 24 units (60 on 10 Oct. 1977), each 625 cm^2 in area. The animals were extracted with the aid of a worm extractor decribed by HUHTA & KOSKENNIEMI (1975). Each sample included subsamples taken from experimental plots treated differently. Due to this, the variance within a sample was high, but because each sample included the same plots, the results are comparable (Table 4).

No definite trend can be seen in the numbers of specimens, but the biomass values reveal a significant loss during the cold winter 1975-76. In May 1976, only a few adult specimens (3 D. octaedra, 1 L. rubellus) were found, and the average individual weight of worms was only 1/4 of that in the previous autumn. Almost all worms obtained were small, newly hatched specimens. Apparently, the populations of these two species were almost totally destroyed during the winter, but the eggs had survived, giving rise to a new generation. Due to the growth of these specimens, the populations gradually recovered, so that in May 1977 the biomass was 17 times higher, and the weight of individuals 10 times higher than in the previous spring. Still only 1 adult worm was found. By the next sampling, the generation of 1976 had reached maturity, and also new juvenile worms had appeared in the populations. (Also Allolobophora

caliginosa was present in some of the test plots, but this species has been omitted from the figures.)

These observations offer strong evidence that hard frosts together with absence of snow may cause severe damage in populations of soil Oligochaets. However, we do not know the real minimum temperatures to which the animals were exposed. In the first case, soil temperatures were measured only at the moment of sampling. In the second case, there was only one measurement, showing that the soil temperature was probably outside the range of the recorder.

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Legends to the Figures:

Fig. 1. Mean daily temperatures (thin solid line), daily minimum at soil surface (broken line) and thickness of the snow cover (thick line) in Nov. 1965 according to the weather station at Seutula, 20 km north from Helsinki. The arrows indicate the dates of sampling.

Fig. 2. Mean daily temperatures (thin solid line), daily minimum at soil surface (broken line) and thickness of the snow cover (thick line) in Dec. 1975 and Jan. 1976 according to the weather station at Tikkurila, 20 km north from Helsinki. The arrow indicates the date when soil temperatures were recorded (cf. text.).

Table 1. Temperatures of humus and numbers of Enchytraeids and Lumbricids in autumn 1965 in three forest sites near Helsinki (data of HUHTA et al. 1967; Site numbers original).

	11 Oct.	25 Oct.	8 Nov.	22 Nov.
Temperature of humus °C				
Site 1	0	+ 5	+ 3	- 4
" 3	0	+ 5	+ 2	- 7
Numbers of Enchytraeidae $m^{-2} \times 10^{-2}$				
Site 1 (Spruce, OMT)	181	190	139	8
" 3 (Pine, CT)	52	29	95	4
" 5 (Pine, CT)	106	93	130	4
Numbers of Lumbricidae m^{-2}				
Site 1	84	60	112	8

Table 2. Temperatures of humus and numbers of Enchytraeids in autumn 1965 in three forest sites in Central Finland (data of HUHTA et al. 1967; Site numbers original).

	4 Oct.	18 Oct.	1 Nov.	15 Nov.
Temperature of humus °C				
Site 7	+ 8	+ 1	+ 6	- 3
" 9	+ 8	+ 2	+ 6	- 4
" 11	+ 6	+ 1	+ 6	- 8
Numbers of Enchytraeidae $m^{-2} \times 10^{-2}$				
Site 7 (Pine, VT)	163	174	166	17
" 9 (Spruce, MT)	67	72	27	11
" 11 (Pine, MT)	130	75	81	6

Table 3. Numbers of Enchytraeids in autumn 1975 and spring 1976 in four bog sites at Lammi (J. Markkula, unpublished).

Sites	1	2	3	4
29 Sept. 1975	1330	6890	25560	3840
10 Nov. 1975	3430	3560	21223	3160
5 May 1976	0	150	800	150
28 May 1976	920	1970	590	490

Table 4. Data on populations of two species of Lumbricids in a spruce stand near Helsinki.

	Total numbers m^{-2}	Total biomass g d.w. m^{-2}	Average individual weight mg	D.octaedra adults	L.rubellus adults
25 May 1975	268	4.6	17	28	22
18 Oct. 1975	119	1.9	16	11	11
20 May 1976	108	0.4	4	3	1
18 Sept. 1976	137	1.8	13	8	0
26 May 1977	153	6.8	44	1	0
10 Oct. 1977	131	2.8	21	17	13

Fig. 1.

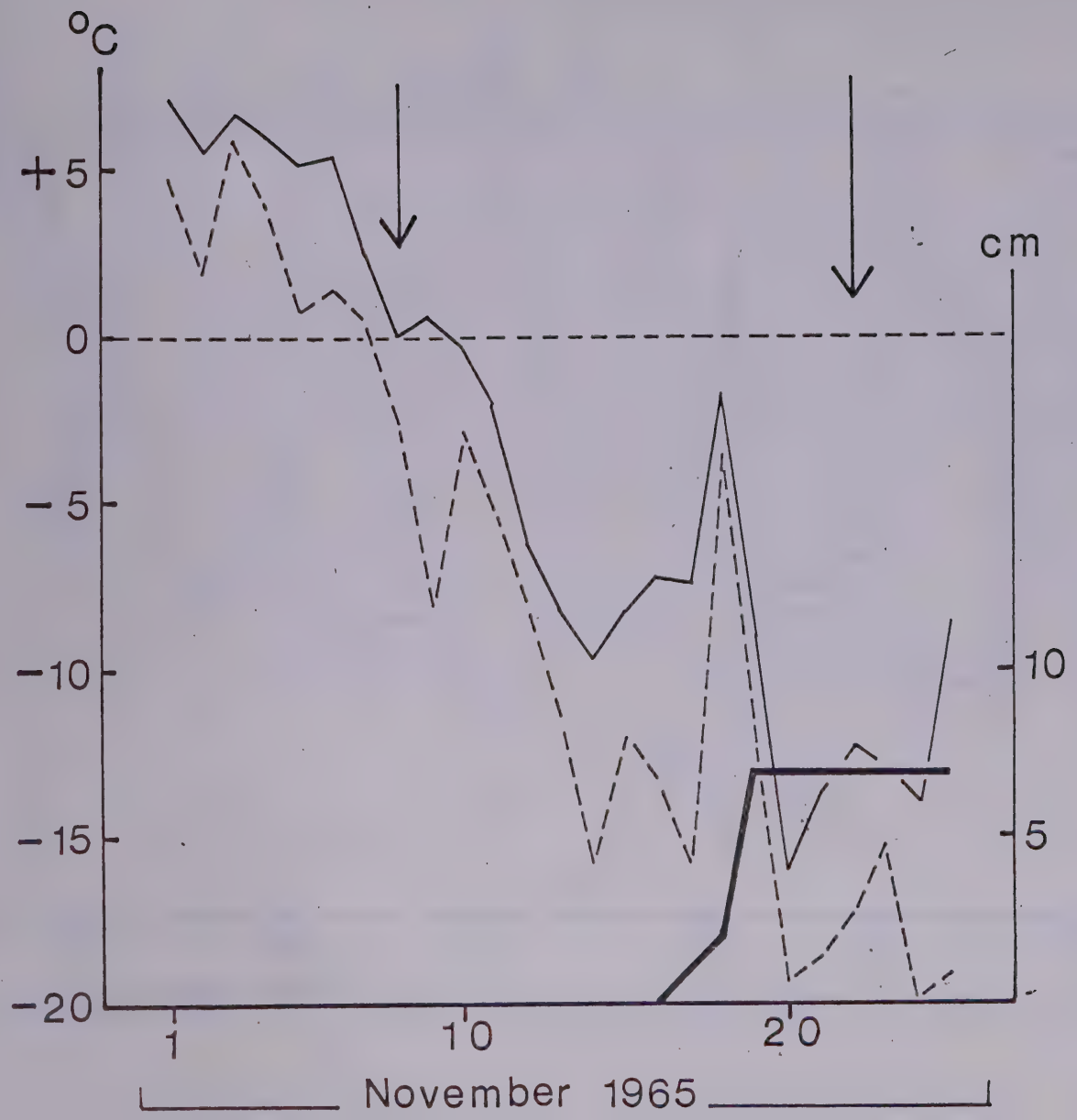
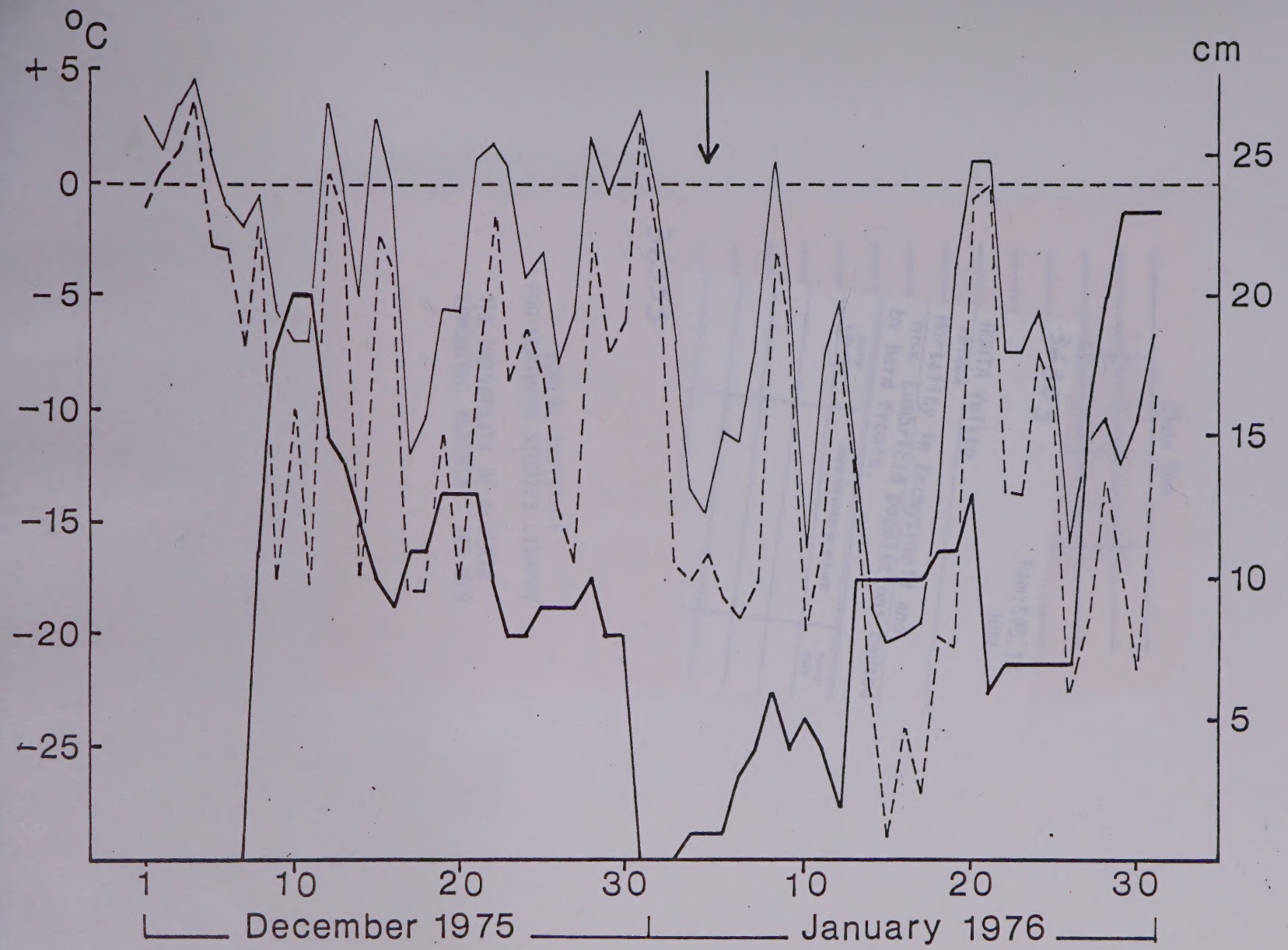


Fig. -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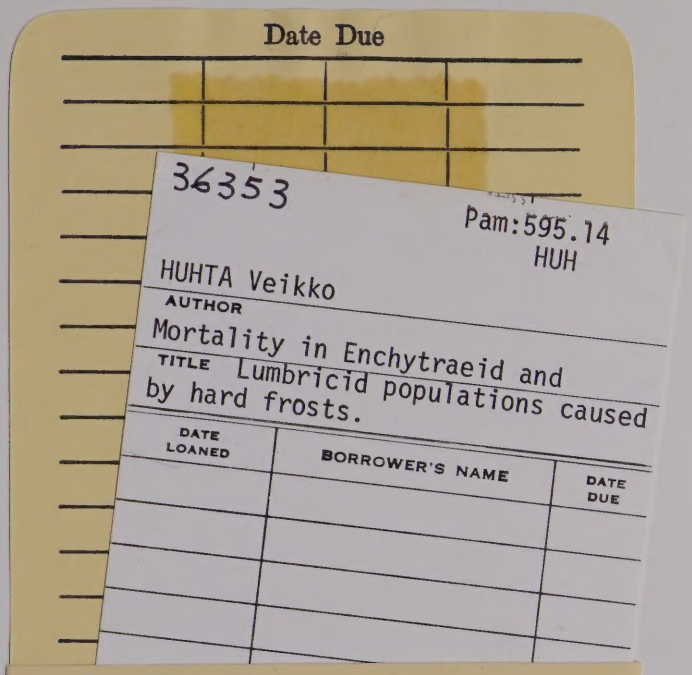

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